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Virtual Modeling As A Support Of Spatial Intelligence In The Education

Josef Sedivy[a*]

[a]University of Hradec Kralove, Faculty of Science, Department of Informatics, Rokitanskeho 62, 500 03 Hradec Kralove, Czech Republic

Abstract

Procedures applied in the current industrial engineering practice put new demands on knowledge and skills of graduates of technical schools, connected with a significant proportion of the use of tools for design, simulation, production technology and data management solutions for the design and technological tasks. Computer-aided engineering activities open up new approaches to creation and analysis of designs and also for creation of processes of manufacturing and assembly. A large number of data sets, the complexity of procedures and the need of sharing of information in various points on the planet with adequate check and security of shared information required the deployment of data management systems and processes.

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Keywords: Scientific modelling, parametric modelling, topological space, computer simulation;

1. Introduction

Today, programs for technical teaching of modeling are used in complete form in almost every field or industry. We see them in technical industries as well as in our everyday life and even in areas where we would never expect to see them. It generally replaces the creativity and imagination of the designer, and in many cases it helps determine collision situations and points during the creation of new products. It generally replaces the creativity and imagination of the designer, and in many cases it helps determine collision situations and points during the creation of new products. Survey is focused on the increase of knowledge of students with the use of visualization and simulation possibilities of computer applications. Implementation of project procedures and results of undertaken experiments are presented in the text.

* Josef Sedivy. Tel.:+-3-321-123-321.
E-mail address: josef.sedivy@uhk.cz

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2. Scientific modelling

Modeling is used not only for solving problems of practice. As in this article we solve computer modeling of virtual prototypes. Scientific modeling is intended also to perform various studies and experiments or simulations of phenomena and processes. It is important to note, however, that the model can in no way cover the actual reality, but a simplified view on a certain part of the real world. For the successful creation and exploitation of the model is necessary to understand the problem we want to model, capture, have a pre-specified target and simultaneously use a good quality source data. Modeling is a multidisciplinary activity, since it can contribute to knowledge of mathematics and physics, systems theory, probability theory, computer science, cybernetics and cognitive science, operations research and others. In practice, we encounter a great variety of different types of models. Only some of them can be understood as models suitable for use in scientific work. Models can be categorized according to the following criteria:

- semantics - what the model represents and acts as such;
- ontology - what means models can be heard;
- gnoseology - both models are used to develop knowledge;
- philosophy - both models reflect reality, what are the implications of the model approach to science and reality, both models can explain by natural laws.

2.1. Theory of modeling

Modeling is a method that is often used in professional and scientific practice in many fields of human activity. The main goal of modeling is not only describing the content, structure and behavior of the real system representing a part of the reality but also describing the processes. The process can be understood as series of transformations that changes the input values to output values. From the system point of view the process is dynamic system in which the values of the characteristic of the system elements are changed under the influence of the external elements. The models are always only approaching of the reality, because the real systems are usually more complex than the models are (e.g. Chromy & Drtina, 2012). The system homomorphism is applied in the process of modeling, which means that each element and interaction between the elements of the model corresponds to one element and interaction of the modeled real system or real process, but the reverse is not true. The model is always to be understood as simplification of the original. If the relation of isomorphism is between the model and real system the original model we could not distinguish between the model and the original. The first step in the process of computer simulation is creation of conceptual model of the studied real system / real process. Conceptual model can be represented in different way. The most used representations are:

- Mathematical equitation;
- Process charts.

Mathematical equitation establishes mathematical model of the studied real system. The model can be obtained either theoretically based on basic physical properties of the system, or numerically by means of the measured values. Determination of parameters of theoretical model developed from empirical data is called system identification.

2.2. Application in parametric modeling

Information technologies offer many opportunities for the application of alternative teaching methods, such as the problem and project teaching techniques and the development of creative teamwork. In order to strengthen cross-curricular relations, the University in Hradec Kralove introduced project teaching classes. One of the projects realized by the school is called the Virtual tour of objects. The technology of virtual reality is based on various fields such as programming, computer graphics, mathematics, but also on various artistic fields. Therefore, the above-mentioned project involves students focused on these fields of study. Students of the Computer Graphics class undergo classical art training and courses, which teach them the basics of computer graphic technology. Participants in the project are organized into two groups including future experts of various disciplines. Some are technically oriented (e.g. programmers) and others are artists (e.g. Chromy, 2012). To achieve creative cooperation between these groups of students is not always an easy task. For practical example we describe with mathemacic tools body. We use concepts such as topological spaces and topological views and n-manifold in $E\ m$. Topological space is a set of subsets X with τ. System τ must satisfy axioms:

1) $\emptyset \in \tau$, $X \in \tau$,

2) the intersection of a finite number of sets of τ must be back in τ

3) the union of any number of sets (and innumerable) of τ is τ again. The system sets τ must be closed to the final penetration and any sum (even with the countless number of elements). File name the topology τ on X. The sets in τ are open sets and their accessories in X closed sets. Topological space is denoted (X, τ).

Subset $U \subset X$ topological space (X, τ) is a neighborhood p point, when there is an element $O \in \tau$, so that $p \in O$ and apply $O \subset U$. Neighborhood of a point will be denoted $p\ U\ (p)$.

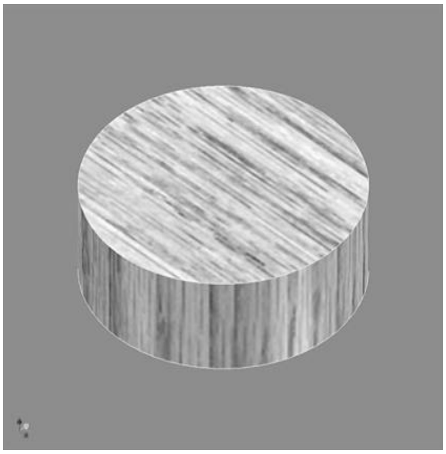

Fig. 1. Topologically simplest element (body)

Fig. 2. Example of real technical body with the whole

View f topological space (X, τ) into a topological space $(X\ ', \tau')$ is continuous if each image in the neighborhood of $p\ (X, \tau)$ is at the same time point f surroundings (p) in $(X\ ', \tau')$. If f is a bijection and $f\ f$ -1 are continuous maps, then called f homeomorfizmem, a topological view. Two topological spaces are topologically equivalent if there is a homeomorphism between them. Homeomorphism is mutually unambiguous mapping between topological spaces that preserves the topological properties. In terms of topology, these two rooms the same properties are the same. Homeorfismus for the definition of an essential element. In describing the body and its boundaries, we introduce the notion of manifold-$n\ E\ m\ N$-manifold in $E\ m$ where $m = n$, such $E\ m$ subset which is homeomorphic with $E\ n$. It is a manifold without boundary. N-in manifold with boundary $E\ m$ is then $E\ m$ subset which is homeomorphic with a positive half-space $E\ n + = \{(x\ 1, .., x\ n) \in E\ n \mid x\ 1 = 0\}$. In practical implementation modeler to check the calculations correct topological elements. To check you can use Euler's formula, this is a necessary condition for correctness. Formula says that the number of walls, edges and vertices is given by the body. We solve first the bodies that have only one surface does not pass by them any holes. They do not contain any internal cavity and the wall is homeomorphic with a circle. Such elements are topologically simple. They are all homeomorphic to the ball. When we describe V number of vertices, edges E number, number of walls F. You can then Euler's formula for this element can be written as:

$$V \cdot F + 2 = E \quad (1)$$

Body on fig. 2is body with a whole (not the internal cavity) is bounded by a single continuous surface, while each wall element is homeomorphic with a circle. This mass is homeomorphic with a sphere with a certain number of closed units. Number of holes is a genus. For the body whose genus is G,

The Euler formula:

$$V + F = E + 2(1 - G) \quad (2)$$

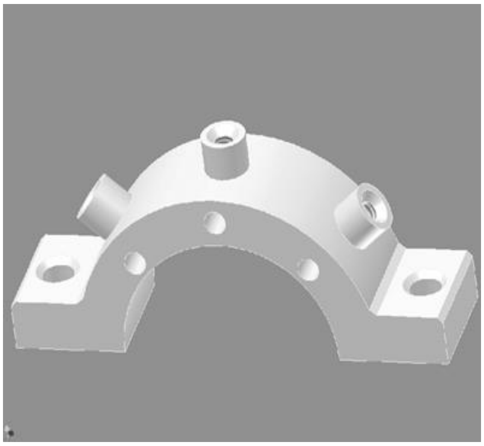

Fig. 3. Example of real technical body with the internal cavity

For housing with an internal cavity, the body is bounded by several separate closed surfaces. Denote the number of surfaces S. It is not necessary that every body panel is homeomorphic with a circle. Each wall is bounded by a single loop edges. L the number of loops on surfaces of solids G genes and the sum of the individual surfaces. Euler's formula has the shape:

$$V + F = E + (L - F) + 2\,(S - G). \tag{3}$$

Process charts establishes process model of the real process. The process models can be described by different way; the most common are flowcharts that described the algorithm of the modeled process. The conceptual model must adequately describe the dependency system outputs on its inputs. Models of real process system will be shown in the following paragraphs of this paper.

3. Computer simulation

Computer simulation of real systems and real processes is one of the most effective methodological tools, especially for the following reasons (e.g. Hubalovsky, 2011):

Computer simulation of real systems and real processes is one of the most effective methodological tools, especially for the following reasons:

- It allows study models of reality that are not analytically solvable models, especially dynamic.
- Process and allows qualitatively and quantitatively classify a large amount of experimental data.
- Allows general theoretical models of experimentally confirm or disprove - validate.

The process simulation follows the process of creating a conceptual model of a real system under study and the real process. The simulation can be understood as a process of transformation of a conceptual model describing the real system simulation model. A typical simulation model can be written both as specialized programming languages that were designed specifically for the requirements of simulations, both for programming can use simulation models and spreadsheets, or standard programming languages. In the literature, therefore, often found the term computer simulations. It is also the basis of our virtual prototypes. From the above considerations it is clear that simulation is a process that runs on your computer. In some publications, therefore, present the concept of computer simulation (e.g. Hubalovsky & Sedivy, 2012).

3.1. Advantages and disadvantages of computer simulation

Advantages and disadvantages of computer simulations are defined. Briefly summarize the main benefits of simulations:

- Simulation allows study systems and processes described by mathematical equations or graphical formalism, but these are solvable only in a certain approximation. Transformation of this conceptual model into a computer program (simulation model) can be obtained from numerical solutions.
- Provides validation and testing a conceptual model.

Simulation of shortening or lengthening the time interval - can speed up or slow down the behavior of processes and phenomena in order to expedite or facilitate research. Exploration and identification process using simulation to optimal setup and management of real process without disruption of this process. Simulation allows you to diagnose problems and understand the complex interactions between the characteristics of a real system. The main disadvantages of simulation include the following: Numerical, discrete solution simulation model is not fully analytical solution - there is some discrepancy between the conceptual model. There is a risk that the simulation model will be "at all costs" accepted as a model of a real system, even though this model is not based on actual real reasonable and generally applicable theory - generally as a conceptual model. In some cases it is easier, less time-consuming and cheaper to use a conceptual model analytical solution than to carry out the transformation of the model simulation (e.g. Hubalovsky, 2012).

3.2. Simulation in CAD and CAE programs

CAE - Computer Aided Engineering are tools for implementing of simulations and engineering calculations on 3D digital models and assemblies created in the CAD module. Computational algorithm works based on Finite Element Method - FEM. In connection with the design of structural design out strength calculations to determine the stress and strain in the loaded part of the structure is usually carried out. A network of elements is defined on a 3D digital model or assembly. Geometric and structural boundary conditions are specified according to functionality of construction. After completion of the calculation the quantitative results for selected construction sites, or qualitative visualization of the monitored parameter on the surface and inside the volume element is to evaluate. Based on the obtained results the construction can be considered as properly designed, undersized or oversized, which is the basis for further editing and optimization of the model. Introduction to CAE module in teaching is possible through case studies and examples of the topics taught in technical mechanics and physics, initially without further theoretical knowledge of finite element method. It enables a gradual transition from analytical solutions to computer-supported technical calculations (e.g. Hubalovsky, 2012). Gradually full use of the work on their own educational projects is expected.

4. Visualization

The concept of visualization is closely related to the concept of simulation. Visualization is a technique that transforms, selects and shows the output data and data obtained from the simulation allows the investigation, analysis and interpretation. Among the commonly used tools in scientific visualization, simulated data are 2D and 3D charts, tables, flowcharts, animated diagrams and more. General principles of engineering design, rules for creation of tools and technology issues of inlet and solidification of the casting material in the actual process of casting were applied for the development of the project. A project of this type was processed by a student in a period of three months.

4.1. Replacement of the real process

The main advantage of simulations is that simulations model allows providing rather big number of the process steps in relatively short time, changing of input parameters and its visualization and optimization of the process. The simulation is very useful from educational point of view. Using the simulation model and visualization of simulation results on the screen, students can better understand the basic features of the processes and systems and develop their intuition. It is also essential that the teaching by means of simulation is much cheaper and faster than the teaching carried by real experiment. In some cases providing the real experiment cannot be feasible.

5. Model verification and validation

Verification and validation are important aspects of the process modeling and simulation. They are essential prerequisites to the credible and reliable use of a model and its results. In modeling and simulation, verification is typically defined as the process of determining if executable simulation model is consistent with its specification – e.g. conceptual model. Verification is also concerned with whether the model as designed will satisfy the requirements of the intended application (e.g. Sedivy & Hubalovsky, 2012). Verification is concerned with transformational accuracy, i.e., it takes into account simplifying assumptions executable simulation model. Typical questions to be answered during verification are:

- Does the program code of the executable simulation model correctly implement the mathematical model?
- Does the simulation model satisfy the intended uses of the model?
- Does the executable model produce results when it is needed and in the required format?

5.1. Validation

In modeling and simulation, validation is the process of determining the degree to which the model is an accurate representation of the real system / real process. Validation is concerned with representational accuracy, i.e., that of representing the real system / real process in the conceptual model and the results produced by the executable simulation model. The process of validation assesses the accuracy of the models. The accuracy needed should be considered with respect to its intended uses, and differing degrees of required accuracy may be reflected in the methods used for validation. Typical questions to be answered during validation are:

- Is the mathematical model a correct representation of the real system?
- How close are the results produced by the simulation executable model to the behavior of the real system?
- Under what range of inputs are the model's results credible and useful?

Validation and verification are both ultimately activities that compare one thing to another. Validation compares real system- real process and conceptual model. Verification compares conceptual model and executable simulation model. Sometimes validation and verification are done simultaneously in one process. Here again let us summarize that the mathematical model that reflects the real system-real process has some limitations and simplifying assumptions (the real system-process and conceptual model are in homomorphic relation). In contrast, the simulation model is only the computer expression of the conceptual model (the conceptual model and simulation model are in isomorphic relationship). Data models and drawings are created in CAD applications. There are a number of tools of different levels. The issue of preparation of projects and their solution is not tied to a specific brand. In spite of the fact, that professional tools are very expensive in practice, there are academic licenses for a symbolic price. Functions for basic analysis and measurement models are integrated in CAD tools. Demanding calculations and simulations are performed by modules CAE (Computer Aided Engineering). Calculations in the structure of models are carried out by finite element method (FEM - Finite Element Method). Generation and verification of the machining process is performed by the CAM module (Computer Aided Manufacturing). Phenomenon of contemporary design and technical preparation of production, including upstream and downstream processes, is management of data and information flows within projects and between projects deploying systems of administration and management of product data - PLM (Product Lifecycle Management). A characteristic of these applications in this category is the integration of CAx data and data file with common formats. A special feature is the ability to define processes and information flows on data and communication within the system. They can form a system of data of developed projects, of standardized parts, of all related documentation and, ultimately, distribution of educational materials, sample CAx solutions and test applications. All of the above modules CAx / PLM tools are available within the installation sets. The skills acquired with experience working on complex projects using the above applications are crucial for adaptation of graduates in professional practice.

5.2. Explanation tools

The current prevailing and rather traditional concept of e-learning provided in virtual university projects is limited to discussions, research and to the evaluation of the LMS environment (Chromy, 2012). Typical examples of the LMS in our universities are environments such as Moodle or WebCT. Today, e-learning is viewed as a rather simple remote administration tool for student projects, remote communication between teachers and course participants, or as a mechanism for external expert supervision focusing on the professional level of individual courses. Professional discussions are still focused on unclear results, while trying to demonstrate the benefits and disadvantages of off-line and on-line learning, in which each approach has its proponents and opponents, both on the student, tutor and course administrator sides. So far no unanimous agreement on what would offer the optimal solution has been found. The reason is not the helplessness or insufficient professional knowledge of people participating in these discussions. Variability of contents plays a role and the specialization of university courses in combination with the individual learning styles of participants in a specific environment of the virtual learning method. The progress in information technology has been changing the forms and methods of education. Application of multimedia supporting elements has improved the quality of the educational process. For example graphical symbols representing sketch links or values of parametrical dimensions are relatively small and usually it is not possible to magnify them together with other entities on the desktop. Therefore, for a visual and schematic job description and to display individual details, it is necessary to record the picture in high definition. Due to the high bandwidth, the use of online technologies is limited by the speed of the relevant Internet connection [7]. Today's lifestyle requires speed and clarity.

6. Research of the use of tools in the education

Progress of project work can be assessed both in the classroom observation, and by analysis of ongoing status of projects that listeners process outside school lessons. Final outcomes of completed projects can be also analyzed. The structure of CAx data enables to assess the level of technical thinking of a student, his spatial imagination and creativity. From this point of view, the most suitable are CAx applications that allow you to achieve the same result in different ways. Due to the material possibilities of schools and to different licensing strategies for different providers of these systems, this requirement is difficult to reach.

Despite this fact CAx data created in any application are a carrier of sufficient amount of information to produce partial conclusions and for subsequent optimization of the concept of teaching, including teaching supports in the form of text and animated electronic materials. Animated materials are created directly through animation and visualisation tools of a used CAx application. They contain procedures of 2D and 3D design and setting up of corresponding simulations.

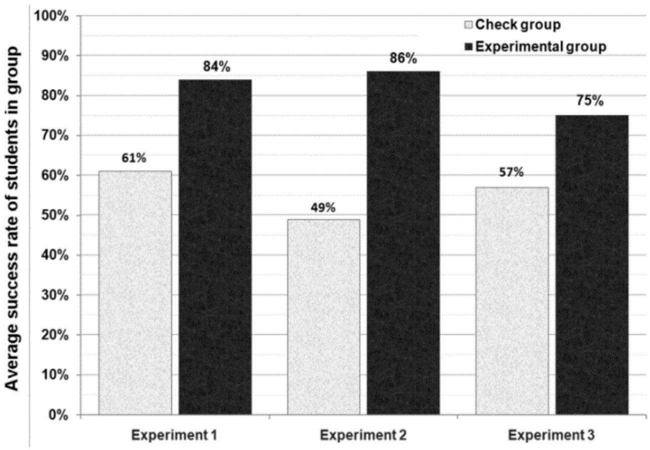

Fig. 4. Verification of deployment of a CAD tool in education - students' success in posttest.

Increase of knowledge and skills is verified by an experiment on two parallel groups in education. Sub-thematic unit is in the experimental group demonstrated with a use of a CAx tool. A classical method without the use of CAx applications is used in the check group. In both groups there are the same initial knowledge and skills, as measured by a pre-test. A post-test is entered and evaluated in both groups at the end of the learning process and this post-test is also repeated in a period of 1 month after completion of the interpretation of the topic. The results of the first post-tests of three final experiments are shown in Figure No. 4. In all cases it was a demonstration of the cutting tool geometry using a CAD model. Several so specified experiments were carried out throughout the research. Selection of pupils to groups was made according to organizational options and criteria, which do not affect the examined parameters. Independence of choice was assessed on the basis of pre-test results. Numbers of pupils in each group were 15 to 30. An experiment was performed repeatedly with an emphasis on ensuring of the same conditions, consisting of the initial knowledge of students, course work, testing and evaluation. Research of attitudes of students and graduates to CAx technologies and to the teaching supported by these instruments is carried out using a questionnaire and an interview. A web questionnaire for obtaining the necessary number of respondents also from remote locations was created for this purpose.

7. Conclusion

The perception of visual information represents largest share of the entire perception done through all our senses. Visual presentation catches the attention, awakens interest and helps with conceptualization. Presentation together with practical demonstration is much more effective. Many terms and thoughts may be understood through visual methods rather than through verbal methods only, for example, practical skills. They should serve to help to expand the visual image. Therefore, it is necessary to keep in mind during the creation of a multimedia teaching educational application to add voice commentaries only to information that is not clear from the presentation itself. Regardless of the applied technology, it is clear that the creation of multimedia teaching supporting elements, and not only in connection with parametrical modeling, may be done by one person/teacher only and therefore it deserves a bigger share of our attention.

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